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EXPERIMENTAL EVALUATION OF PLASTIC FILMS FOR USE AS AIRBAG VENT BLOWOUT PATCHES

BY

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The objective of this investigation was to examine the use of plastic films as vent blowout patches for airbags which are being considered as an impact energy absorber for airdrop cargos. Bursting air pressures of five plastic films were measured in a pneumatic test facility. Measurements showed that circular films made of low density polyethylene, polyethylene terephthalate, and oriented polypropylene are suitable to be used as airbag vent blowout patches. However, their final sizing and selection should be determined from full-scale airbag drop tests.

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PREFACE

The present investigation was conducted in the Plastics Engineering Department of the University of Lowell from October 1, 1987 to September 30, 1988 under Work Unit No. 1L162786D283AH002, Analysis of Performance of Multiple Airbag Platform System. The investigation was Mr. H.H. Tseng's research thesis for his Master's of Engineering Degree.

Airbags are being considered by the U.S. Army as an alternative to paper honeycomb currently used for soft landing of airdropped payloads. This report summarizes some of the work being conducted to achieve this goal.

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EXPERIMENTAL EVALUATION OF PLASTIC FILMS
FOR USE AS AIRBAG VENT BLOWOUT PATCHES

Introduction

The steady descent velocity of a payload airdropped by U.S. Army parachutes (Fig.1) is about 28 ft/s. During ground impact at this velocity, an energy absorber is needed to dissipate some of the impact energy and to provide structural protection for the payload. The U. S. Army currently uses paper honeycomb as the energy absorber. Strategic positioning of paper honeycomb between the payload, such as a vehicle, and the platform (Fig. 2) is a time consuming and labor intensive process. Airbags are presently being investigated by the U.S. Army as an alternative impact energy absorber for airdrop.

Numerous studies have been conducted on airbags.[1,2,3,4,5] An airbag, in its simplest form, is a fabric enclosure with a fixed vent opening. When it is attached to the underside of an airdrop platform and is compressed at ground impact, its air pressure increases and air is vented through the fixed vent opening. The high pressure air decelerates the payload by transmitting a retarding force against the platform. One major problem of such a simple airbag is its tall height (generally >4') that makes it susceptible to ground winds and payload tipover during ground impact. A recent analytical

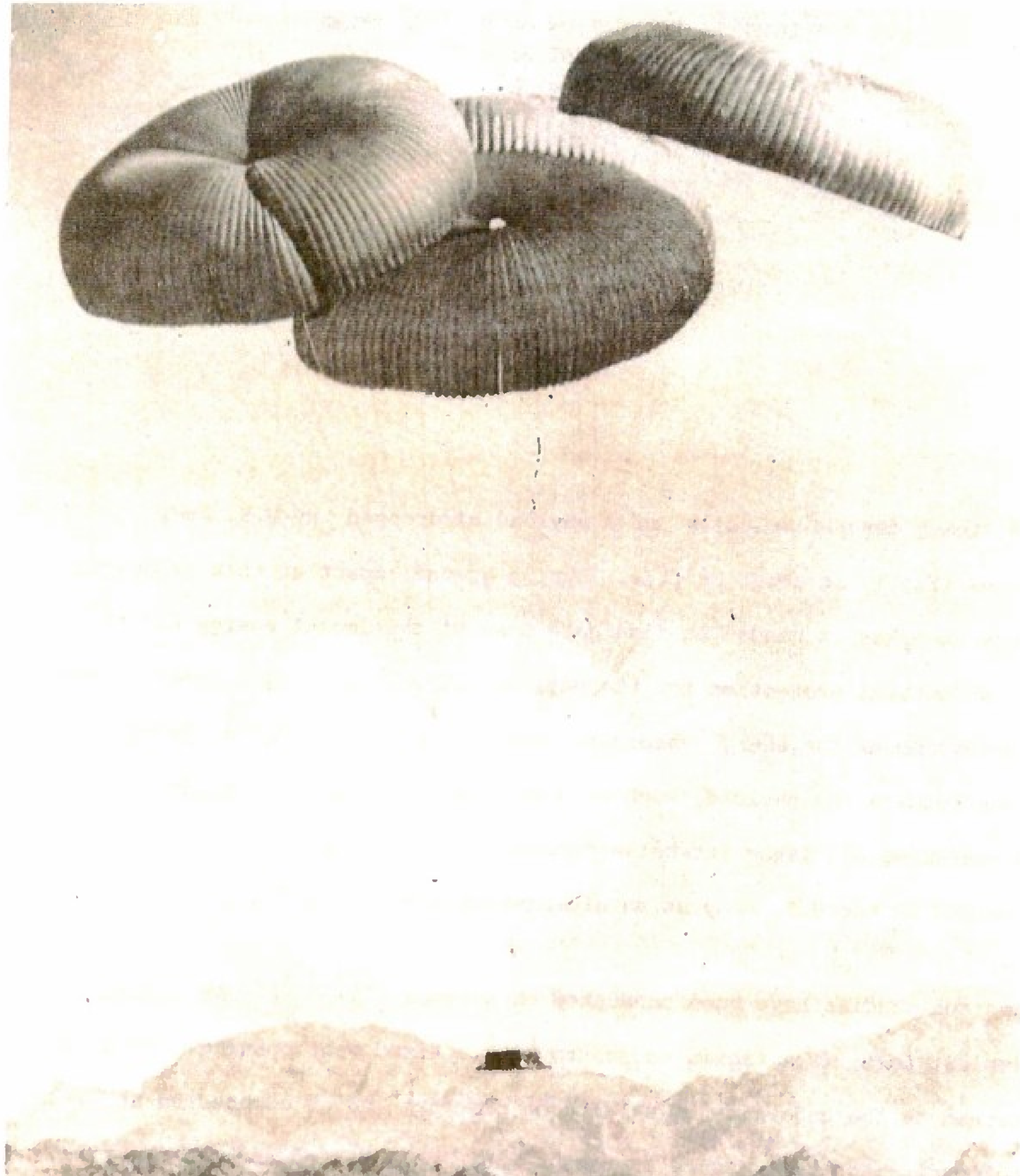


Figure 1. Photograph showing steady descent of a payload airdropped by U.S. Army parachutes.

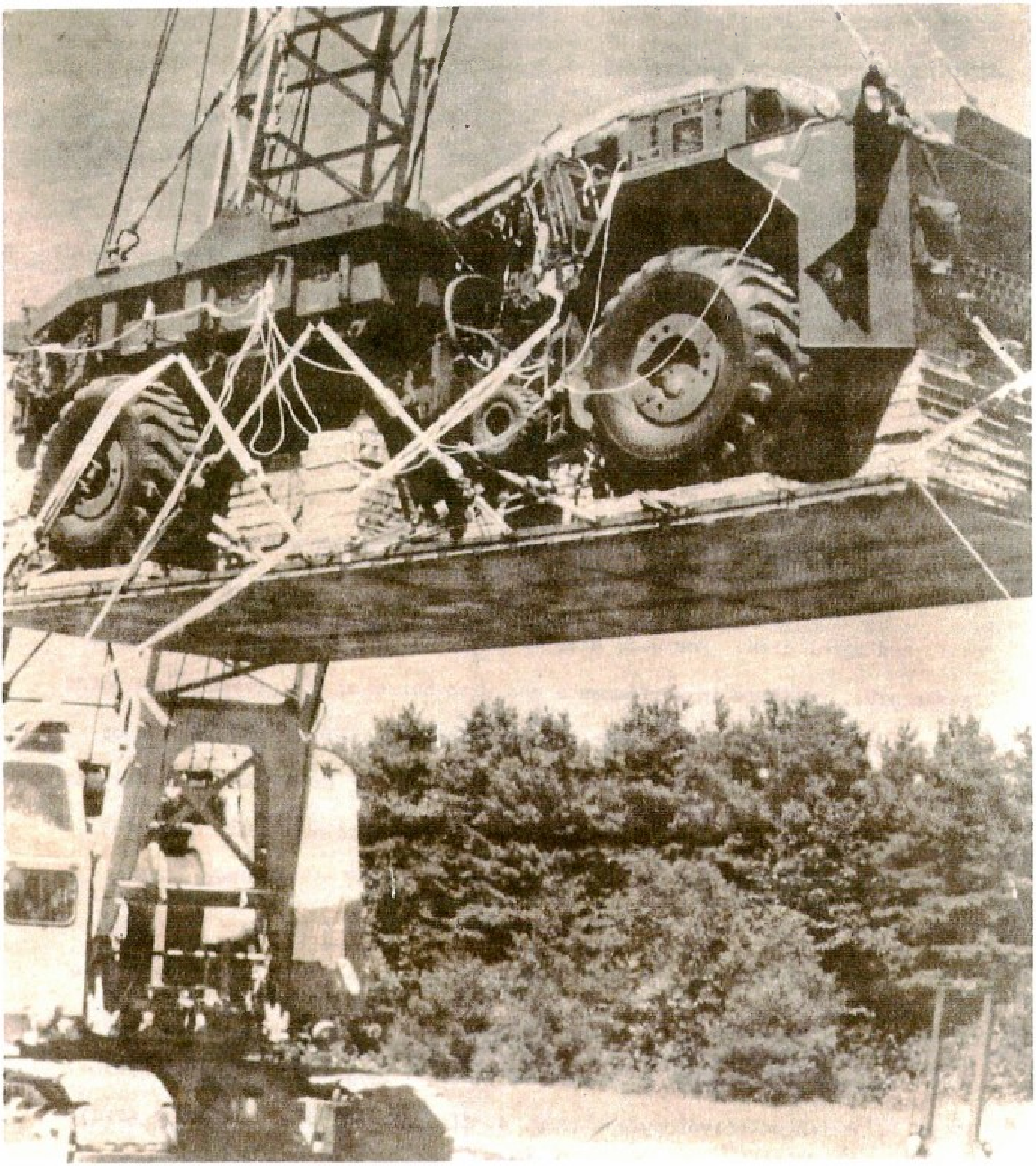


Figure 2. Photograph showing a U.S. Army vehicle cushioned by paper honeycomb and mounted on a platform for airdrop.

study[6] showed that an airbag sealed by a vent blowout patch during part of the airbag's compression stroke at ground impact, the height can be reduced so that the platform and the payload would become less susceptible to turnover. This technique was applied in an airbag system for a remote piloted vehicle.[7] For U.S. Army airdropped payloads of up to 60,000 lbs, mounted on sections of a Type V platform, it is desirable to use vent blowout patches with bursting air pressures ranging from 1 to 20 pounds per square inch gauge (psig). An experimental program was conducted to investigate plastic films and their bursting strengths for airbag vent blowout patch application. This report details the results of that investigation.

EXPERIMENTS

Blowout Patch Materials

A blowout patch is basically a pressure relief valve and various materials have been used for blowout patches. They include rubber membrane, aluminum foil, and metal disk. For U.S. Army airdrop, the material has to be simple, inexpensive, reliable in performance and with bursting air pressures as cited above. Plastic films were chosen for this investigation mainly because of their varying bursting air pressures as a function of thickness, diameter, and material. Burgman and Calderwood[8] did a study in this area, but their film diameters were too large (>12 in.) and their bursting air pressures were limited (<10psig).

For the present investigation, the following five plastic materials were chosen:

1. linear low density polyethylene (PE), 2. polyethylene terephthalate (PET), 3. oriented polypropylene (PP), 4. flexible polyvinyl chloride (PVC), and 5. polyurethane (PU).

The structure of polymeric materials can be divided into three categories: amorphous, crystaline, and oriented. The PE, PET, PP, and PVC are partly amorphous and partly crystalline; PU is amorphous. PVC and PU are more flexible than PE, PET, and PP.

Based on the physical and mechanical properties of the five plastic films and some preliminary stress-strain calculations, 4"- and 6"- diam. plastic films were chosen for testing. Their thicknesses are shown in Table 1.

Table 1
List of Plastic Materials

FILM MATERIAL	TRADE NAME, TYPE	THICKNESS (INCH)
LINEAR LOW DENSITY POLYETHYLENE	Loadmaster E	0.00053
	Loadmaster S	0.00080
	Loadmaster H	0.00120
POLYETHYLENE TEREPHTHALATE	Mylar(R) Type A	0.00048
	Mylar Type A	0.00092
ORIENTED POLYPROPYLENE	AP-1	0.00050
	AP-1	0.00100
	AP-1	0.00150
FLEXIBLE POLYVINYL CHLORIDE	Resinite(R) PS-26	0.00080
	Resinite PS-26	0.00100
	Resinite PS-26	0.00200
	Resinite PS-29	0.00065
POLYURETHANE	PS 8010	0.00100
	PS 8010	0.00500
	PS 8010	0.01000

Test Facility and Procedure

Vent blowout patches of airbags burst in a biaxial manner (as opposed to uniaxial tensile failure). To determine the size and material of selected plastic films as functions of bursting air pressure, a pneumatic inflation test system shown in Figs. 3 and 4 was constructed. The test system consists of a high-pressure air supply line (S in Fig. 3) that pressurizes a pressure test chamber (E) on which a circular plastic film (F, blowout patch) is mounted for bursting tests. The air supply and pressure are controlled by an on-off valve (A), a regulating valve with a pressure gage (B), a solenoid valve (C), and a pressure gage (D). The air pressure inside the test chamber E is measured by a pressure transducer (G) and recorded by a strip-chart recorder (I). The deflection (vertical displacement) of the plastic film F is measured by a video system consisting of a video camera (J) with a 30 frames/sec recording speed, a scale screen (K), and a signal light (L) connected to the solenoid valve C.

The high pressure test chamber E is a 4-in high and 12-in inside diameter cylinder made of 0.75-in thick steel. A circular clamp frame, which holds a plastic film test sample, is mounted on top of the chamber. The clamp frame consists of two plates, with a circular opening (4-in to 6-in diam) in the center, that tightly clamp the plastic film to seal the test chamber during a bursting test.

In a bursting test, the circular plastic film for testing is first carefully mounted in the clamp frame on top of the adjusting chamber E. Air pressure of either 25 psig or 50 psig is set by adjusting the regulating

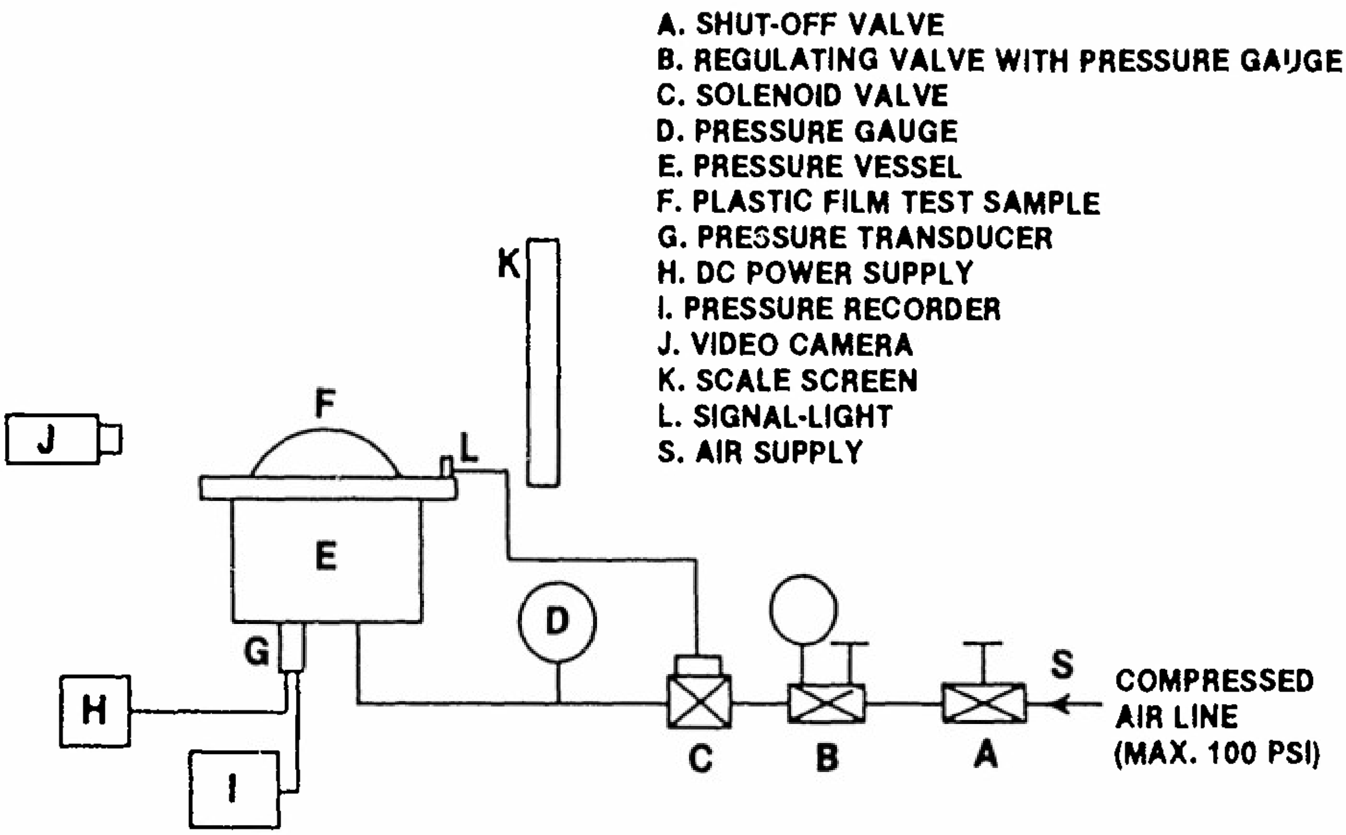
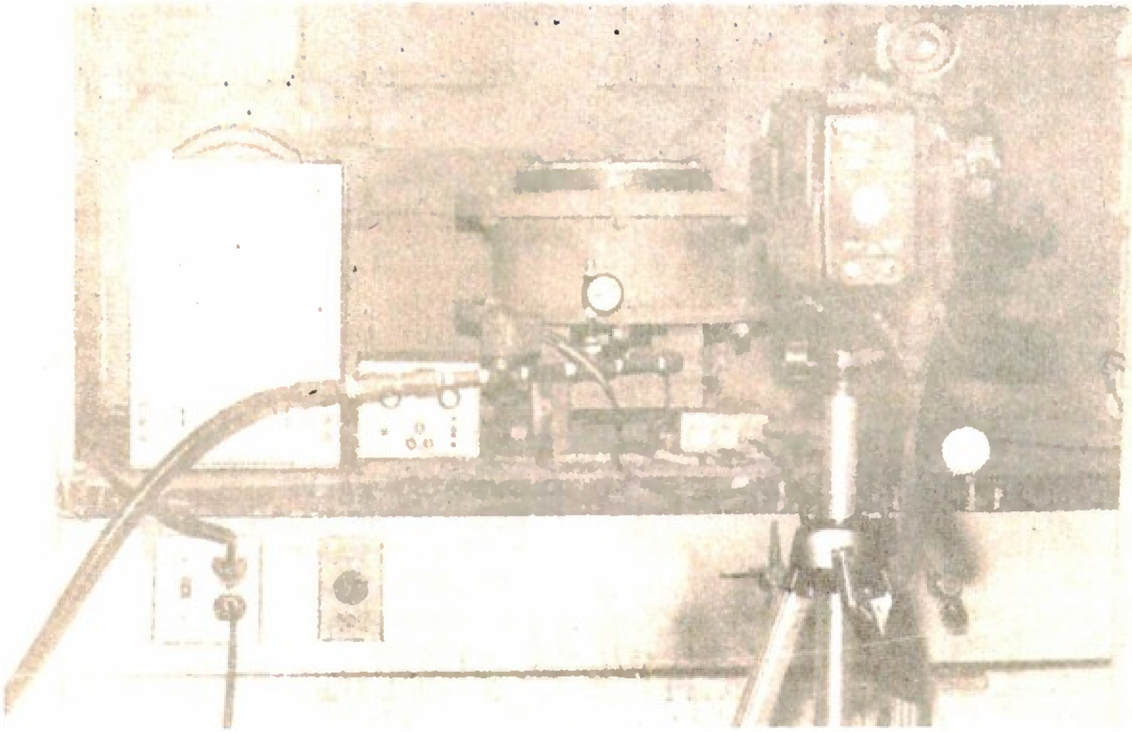


Figure 3. Schematic of set-up for pneumatic bursting tests of plastic films



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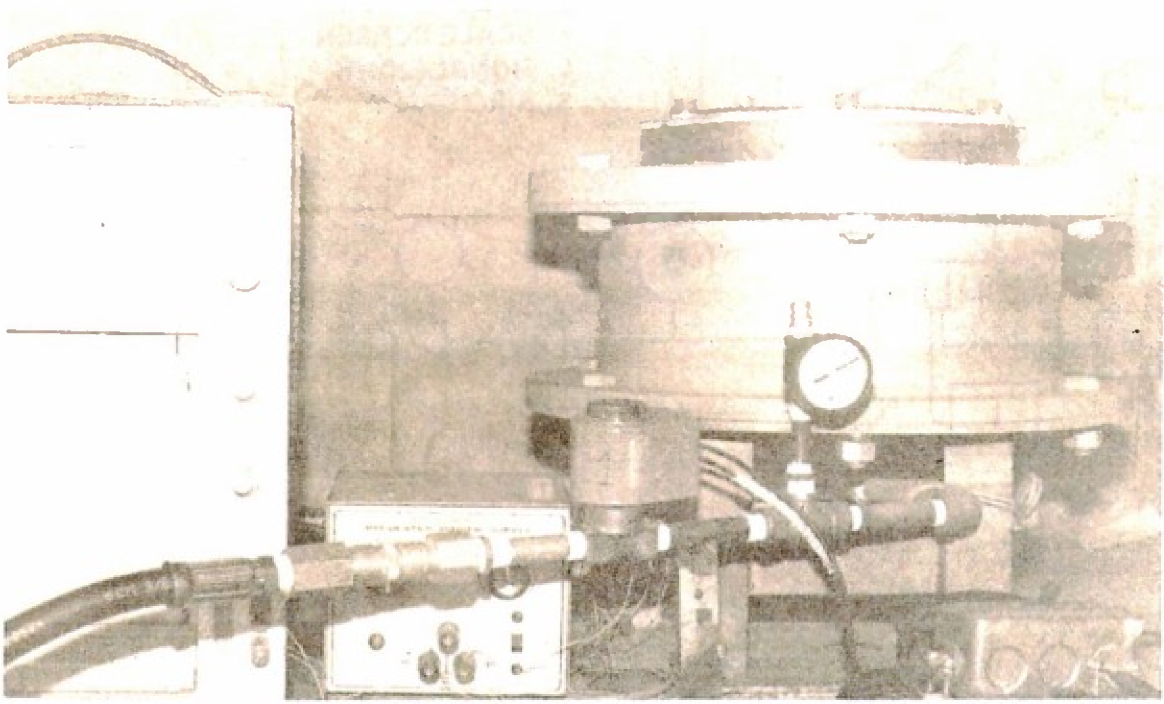

b

Figure 4. Photographs of test set-up: a. Overall test set-up. b. Pneumatic test chamber.

valve B. After the air pressure reaches the set pressure indicated by B, the solenoid valve C is turned on to let the high pressure air into the test chamber E. Simultaneously, C also turns on the signal light L, indicating time zero on the scale screen K. Concurrently, the recorder I records the air pressure-time history in E, and the video camera J records the deflection-time history of F on K. When the air pressure in E ultimately reaches the bursting air pressure, the plastic film bursts. The test is then completed. To investigate the repeatability of the bursting air pressure, at least six identical tests were conducted for each plastic film (Table 2).

After a test, the video recording of the deflection is played back on a TV screen to determine the deflection-time history, which is then correlated with the pressure-time history to obtain the pressure-deflection profile.

Test Results and Discussion

Bursting Air Pressure

Representative chamber air pressure measurements for the five plastic materials during bursting tests are shown in Fig. 5-9. It is seen that air pressure increases as compressed air is being injected into the chamber which is sealed hy tne plastic film. When the pressure reaches the bursting point, ranging approximately from 1 to 20 psig, the plastic film bursts and releases the chamber pressure. This is indicated by the abrupt decrease in the air pressure. Bursting of the PE, PET, and PP films is distinct. But bursting of the flexible PVC and PU films is not as distinct, as indicated by their wavy pressure profiles before bursting. For airbag blowout patch application that requires rapid bursrting, these flexible films may not be suitable; whereas the less flexible PE, PET, and PP films should be more appropriate.

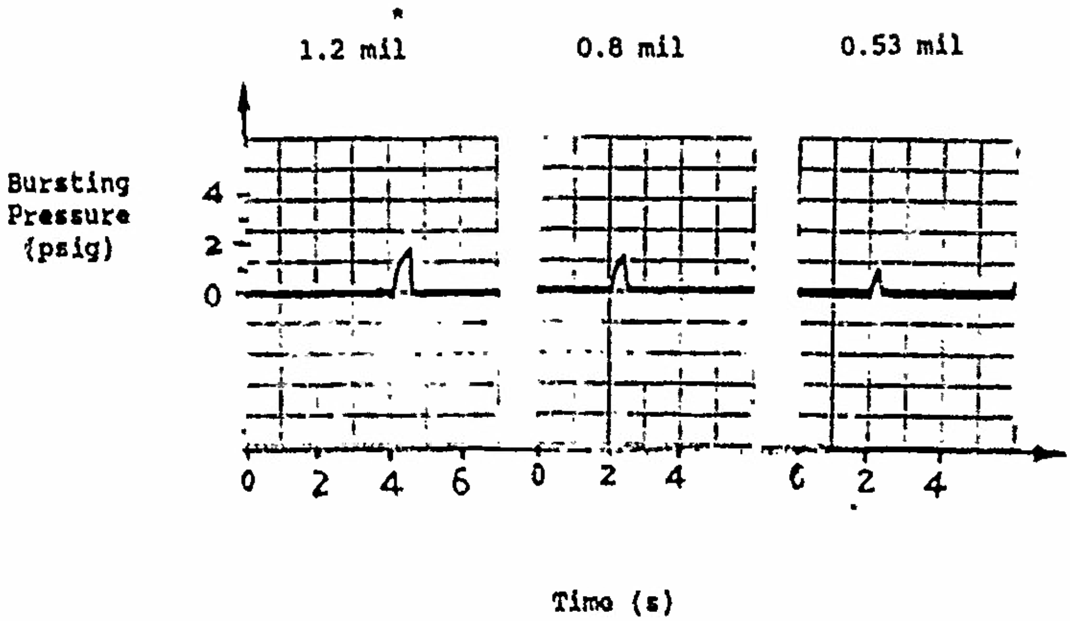

Figure 5. Bursting air pressure measurements of 4"-diam. low density polyethylene films.

* 1 mil = 10^{-3} in.

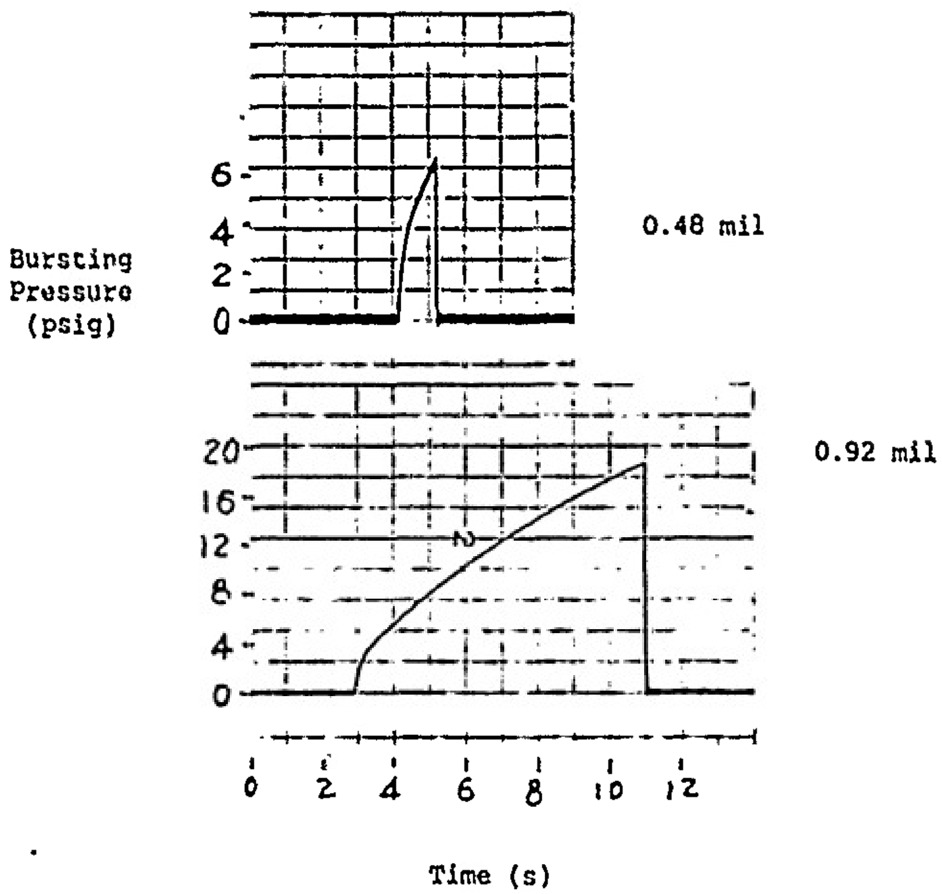

Figure 6. Bursting air pressure measurements of 4"-diam. polyethylene terephthalate films.

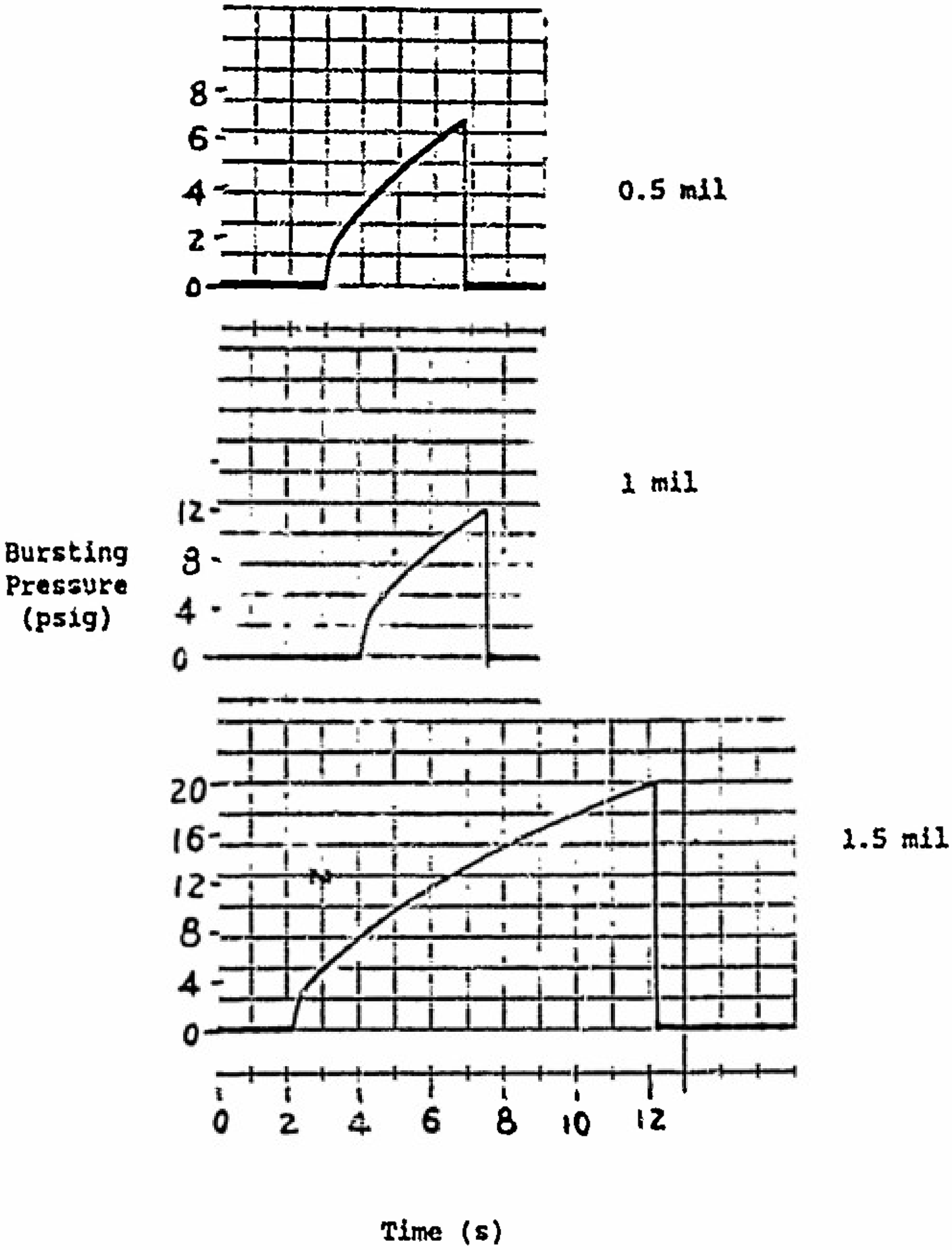

Figure 7. Bursting air pressure measurements of 4"-diam. oriented polyproplyene films.

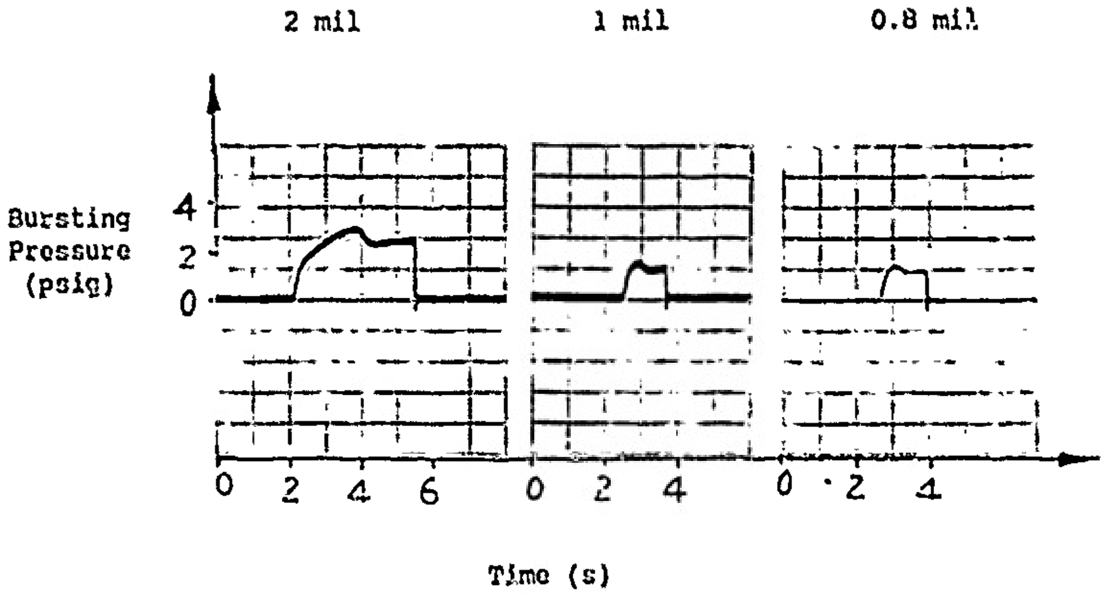

Figure 8. Bursting air pressure measurements of 4"-diam. polyvinyl chloride films.

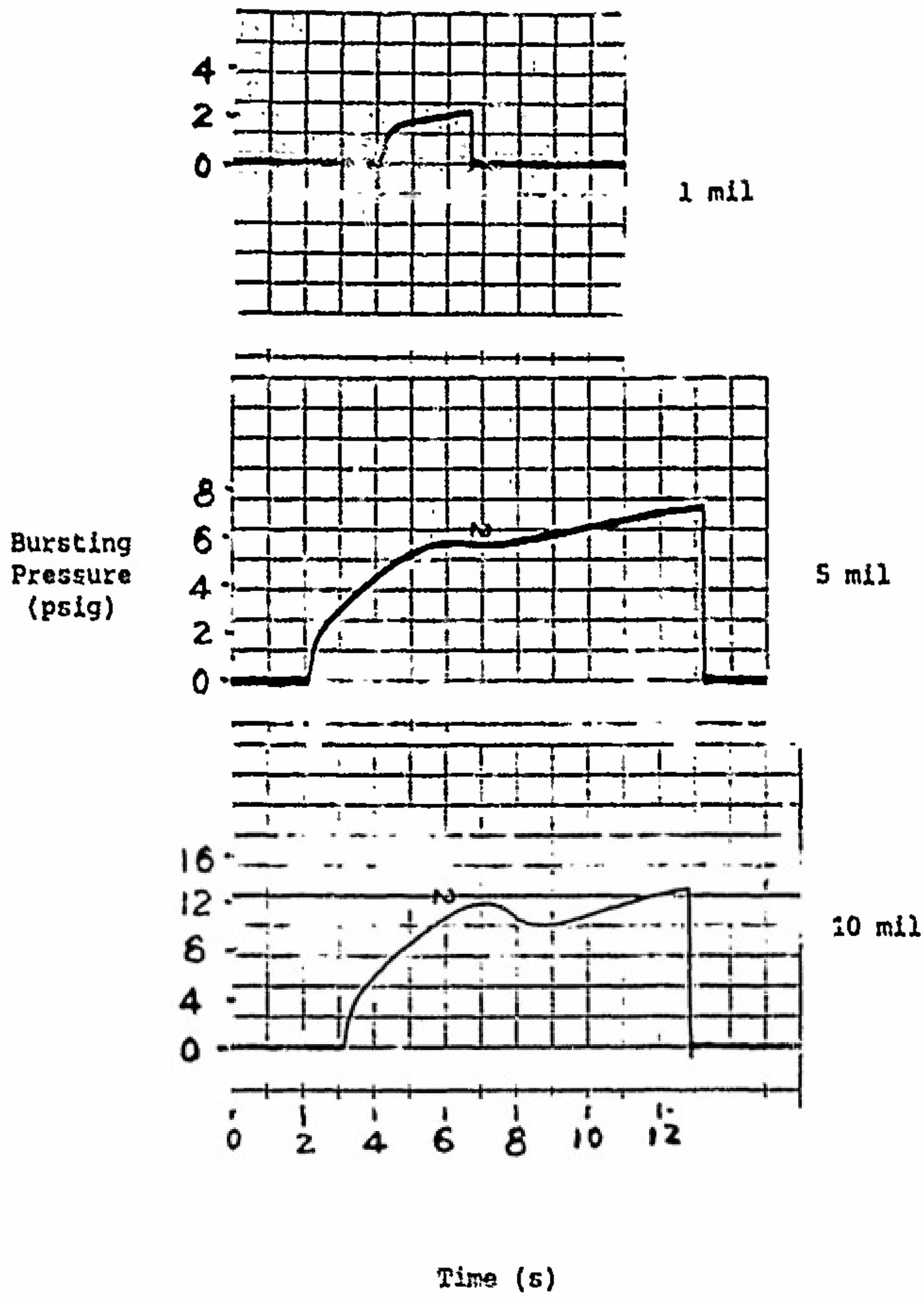

Figure 9. Bursting air pressure measurements of 4"-diam. polyurethane films.

Bursting air pressures from all the tests were determined from pressure measurements as shown in Figs. 5-9; they are presented in the Appendix along with average values. Average bursting air pressures and their standard deviations of the five plastic films are summarized in Table 2. It is seen that the PE, PET, and PP films provide a wide range of bursting air pressures from 1 to 20 psig, a range that is suitable for U.S. Army airbag application. All standard deviations are less than 15% of the average values, except for the 4"-diam, 5-mil PP film (35.7%). This high standard deviation is mostly due to the relatively stiff and thin 5-mi PP films that occasionally present difficulties in applying an even grip by the two clamp plates.

The average bursting air pressures of the three more suitable plastic films, PE, PET, and PP (Table 2) are plotted in Fig. 10 as a function of film thickness. It is seen that bursting air pressure increases linearly with film thickness but decreases with film diameter. Fig. 10 serves as a guide in selecting a vent blowout patch for a bursting air pressure ranging from 1 to 20 psig. It should be noted that Fig. 10 should be used only as a guide because in addition to thickness and diameter, the bursting strength of a plastic film is also dependent on the rate of applying the air pressure. Trial impact bursting tests of the selected plastic film mounted on the airbag with a simulated payload should be conducted first to examine the bursting air pressure. Additional tests will then be conducted to refine the selection to satisfy the desired bursting air pressure.

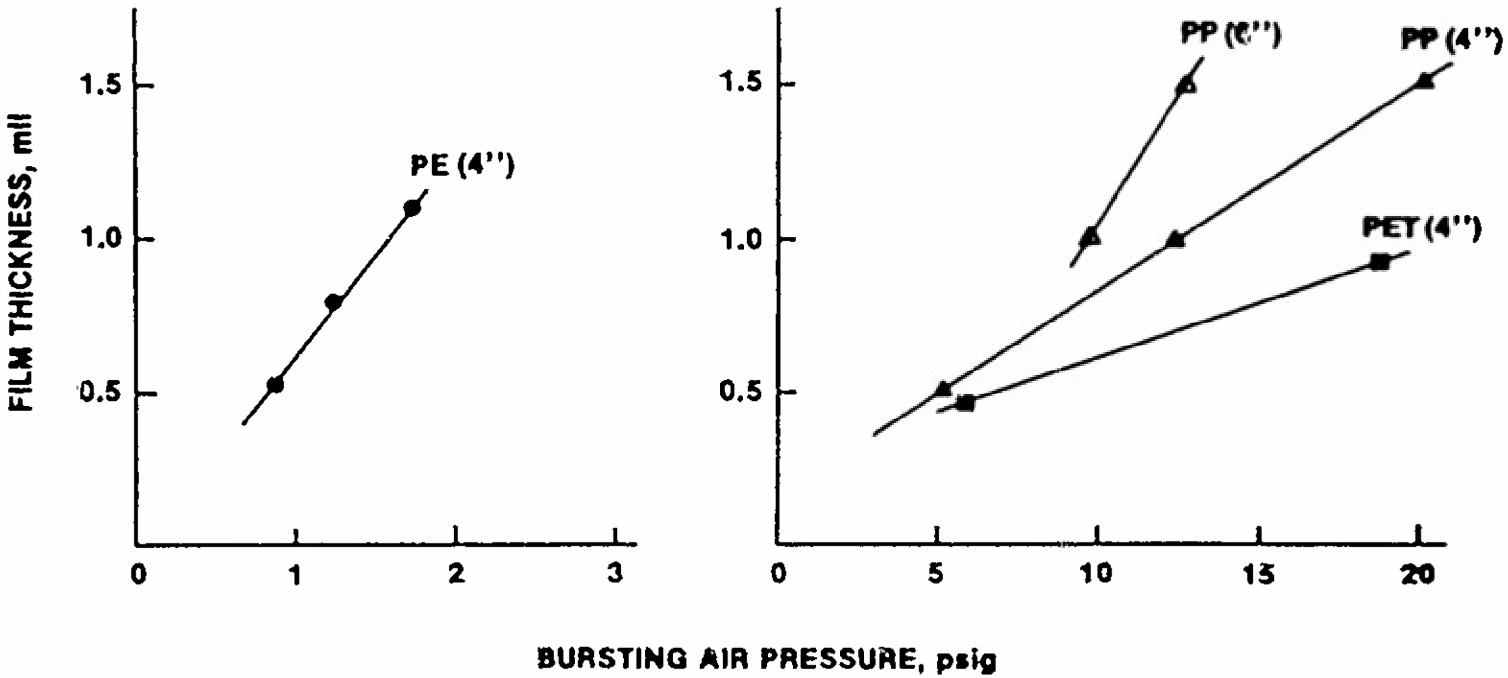

Figure 10. Measurements of bursting air pressure as a function of plastic film thickness, diameter (4" and 6"), and material.

Table 2

Average Bursting Strengths of Plastic Films

FILM MATERIAL	THICKNESS (INCH)	DIAM. (INCH)	BURSTING STRENGTH (PSIG)	STANDARD DEVIATION (PSIG)
LINEAR LOW DENSITY	0.00053	4.0	0.84	0.06
POLYETHYLENE	0.00080	4.0	1.21	0.06
	0.00120	4.0	1.71	0.08
POLYETHYLENE	0.00048	4.0	5.71	0.62
TEREPHTHALATE	0.00092	4.0	18.63	0.62
ORIENTED	0.00050	4.0	5.13	1.83
POLYPROPYLENE	0.00130	4.0	12.34	1.27
	0.00150	4.0	20.10	2.61
	0.00100	6.0	9.68	0.83
	0.00150	6.0	12.71	1.07
FLEXIBLE	0.00080	4.0	1.21	0.09
POLYVINYL CHLORIDE	0.00100	4.0	1.23	0.03
	0.00200	4.0	2.37	0.11
	0.00065	4.0	1.04	0.09
POLYURETHANE	0.00100	4.0	2.11	0.16
	0.00500	4.0	7.91	0.31
	0.01000	4.0	13.03	0.[illegible]
	0.01000	6.0	7.83	0.49

Air Pressure and Film Deflection

As mentioned earlier, air pressure and film deflection measurements were correlated to obtain air pressure - film deflection profiles. Typical profiles are shown in Figs. 11-17. The overall shape of the profiles resembles stress-strain curves of ductile materials. The less flexible PE, PET, and PP films behave like a brittle material; as shown in Figs. 11-14, their profiles show a linear behavior until bursting occurs. The more flexible PVC and PU films behave like a ductile material; as shown in Figs. 15 and 16, their

profiles show a linear behavior first, then a deformation under a relatively constant air pressure until bursting ultimately occurs. Figs. 10-18 also show that as film thickness increases or diameter decreases, bursting air pressure increases as expected.

Conclusion

Bursting air pressures of five plastic films have been measured for airbag vent blowout patch application. The measurements show that circular films made of low density polyethylene, polyethylene terephthalate, and oriented polypropylene are suitable for this application. The measurements provide a data base for selecting a blowout patch having a bursting air pressure from 1 to 20 psig. However, trial bursting tests of the selected blowout patch mounted on the airbag along with a simulated payload should be conducted first to refine the selection (e.g., small changes in film thickness or diameter). The final selection should be based on the results of these trial drop tests.

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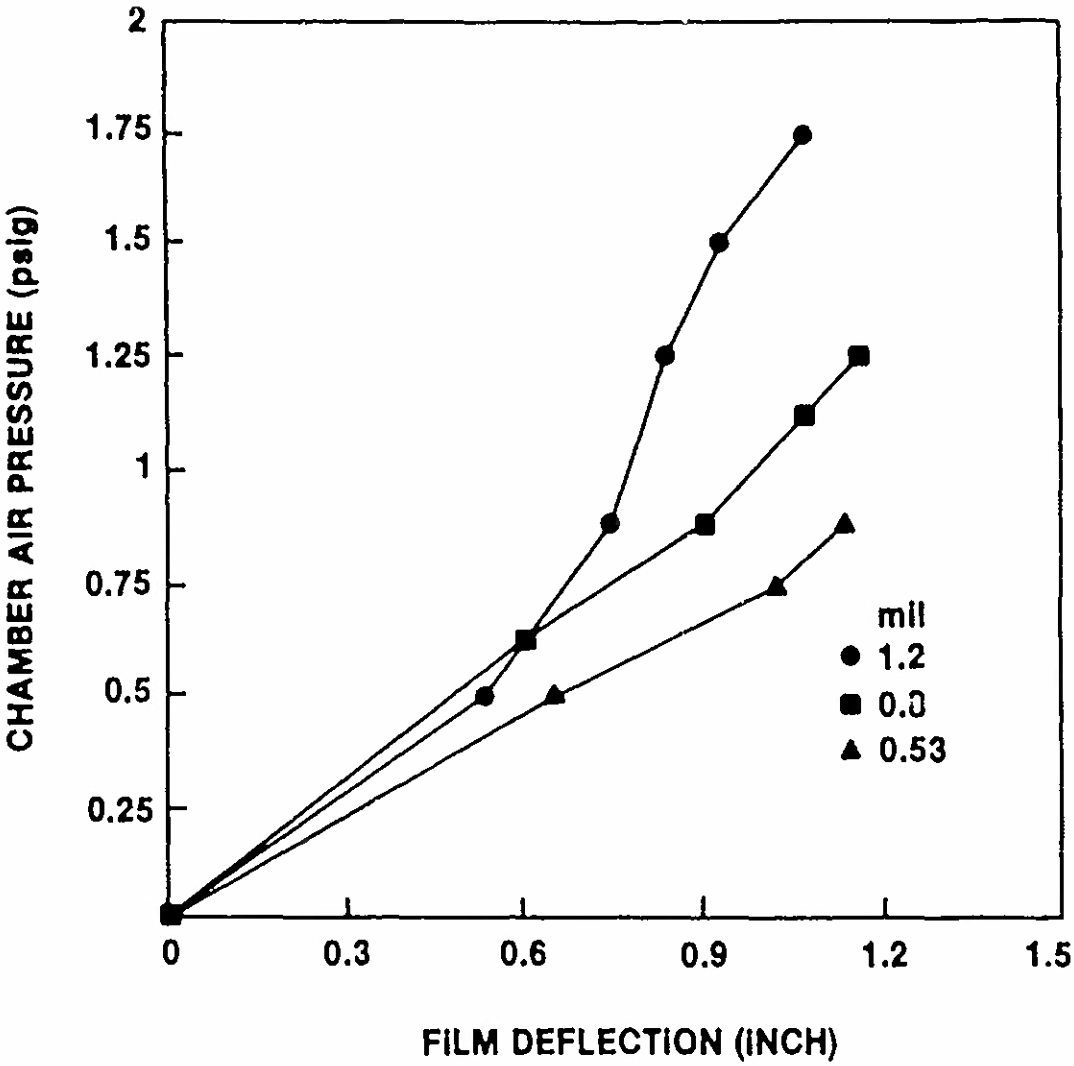

Figure 11. Measurements of chamber air pressure vs film deflection for 4"-diam. low density polyethylene films.

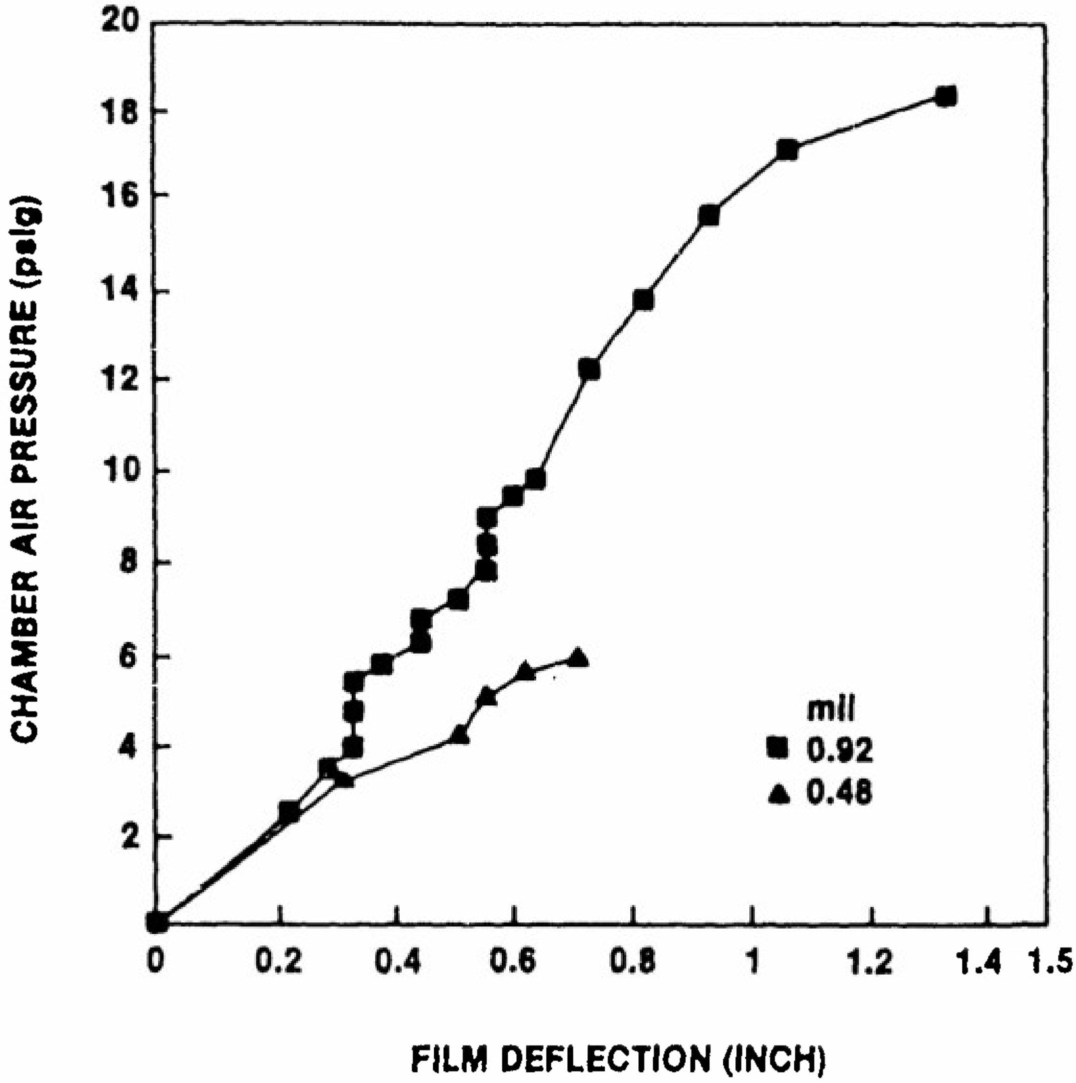

Figure 12. Measurements of chamber air pressure vs film deflection for 4"-diam. polyethylene terephthalate films.

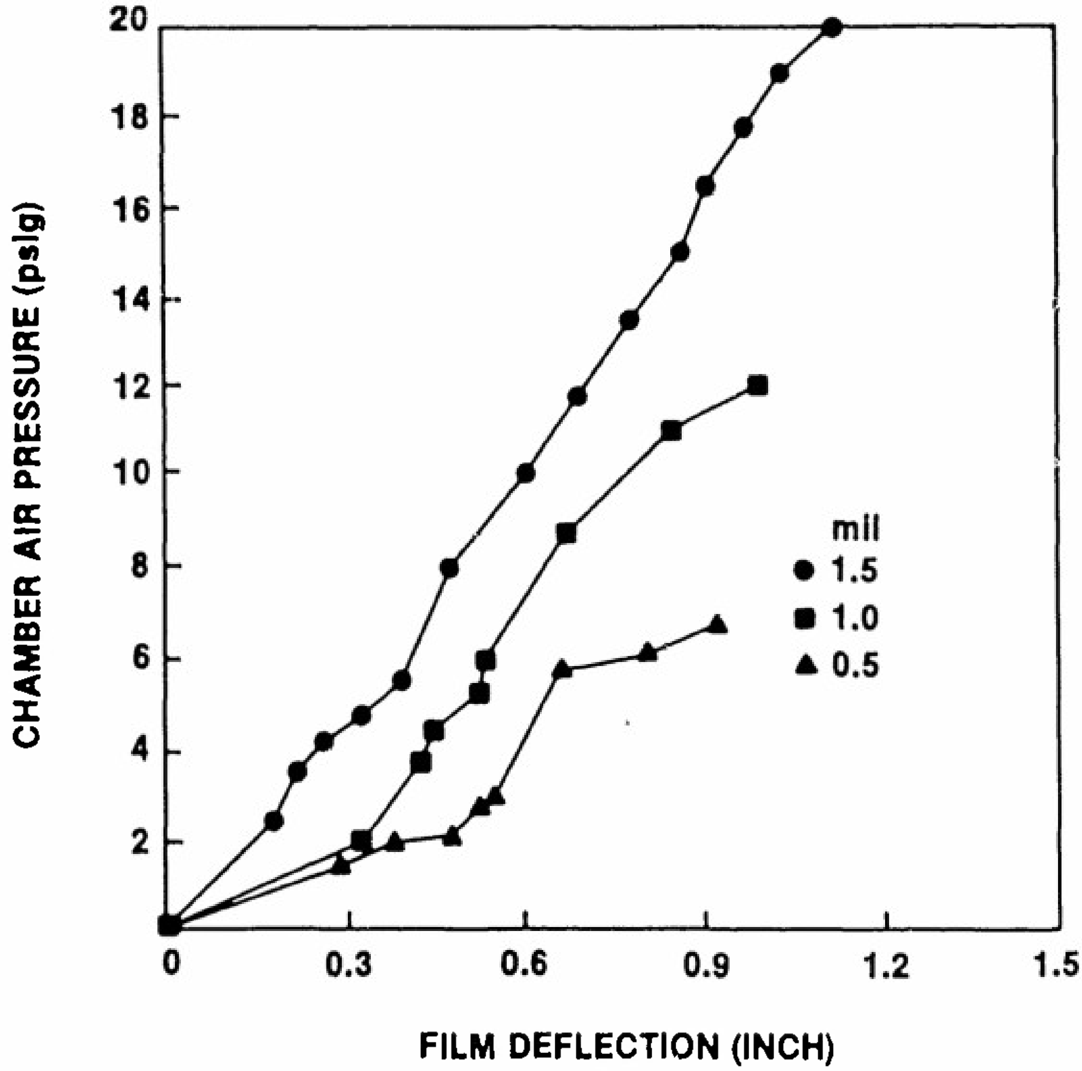

Figure 13. Measurements of chamber air pressure vs film deflection for 4"-diam. oriented polypropylene films.

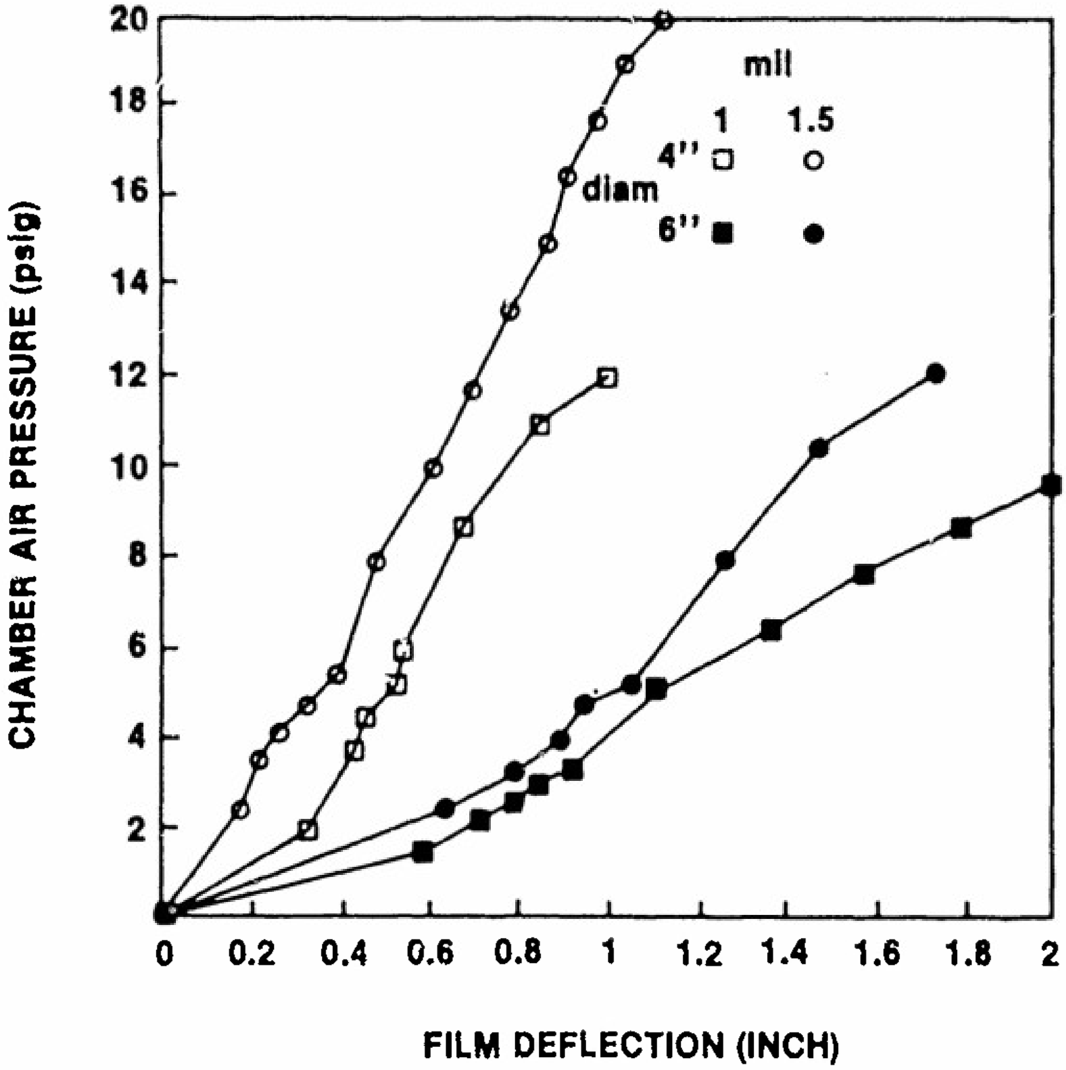

Figure 14. Measurements of chamber air pressure vs film deflection for 4"- and 6"- diam. oriented polypropylene films.

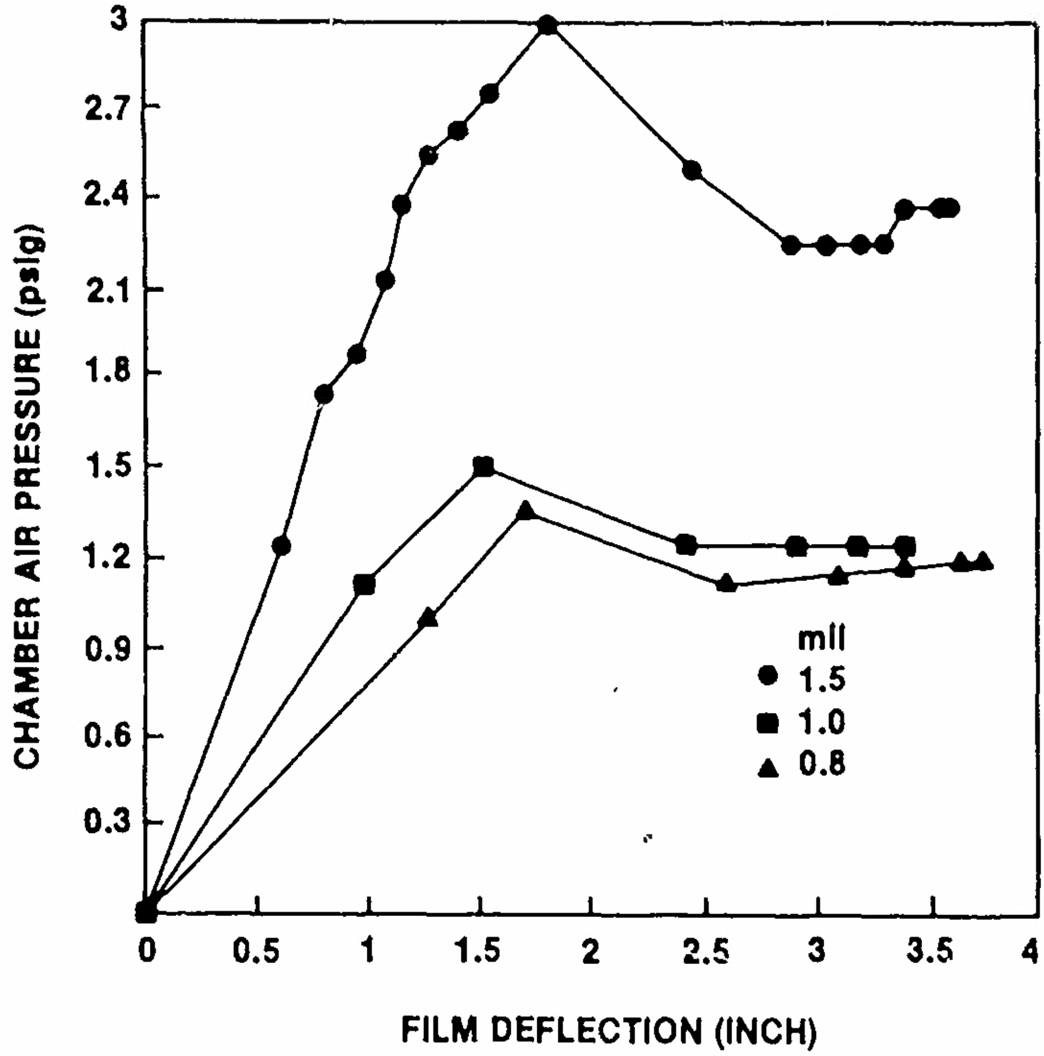

Figure 15. Meassurements of chamber air pressure vs film deflection for 4"-diam. polyvinyl chloride films.

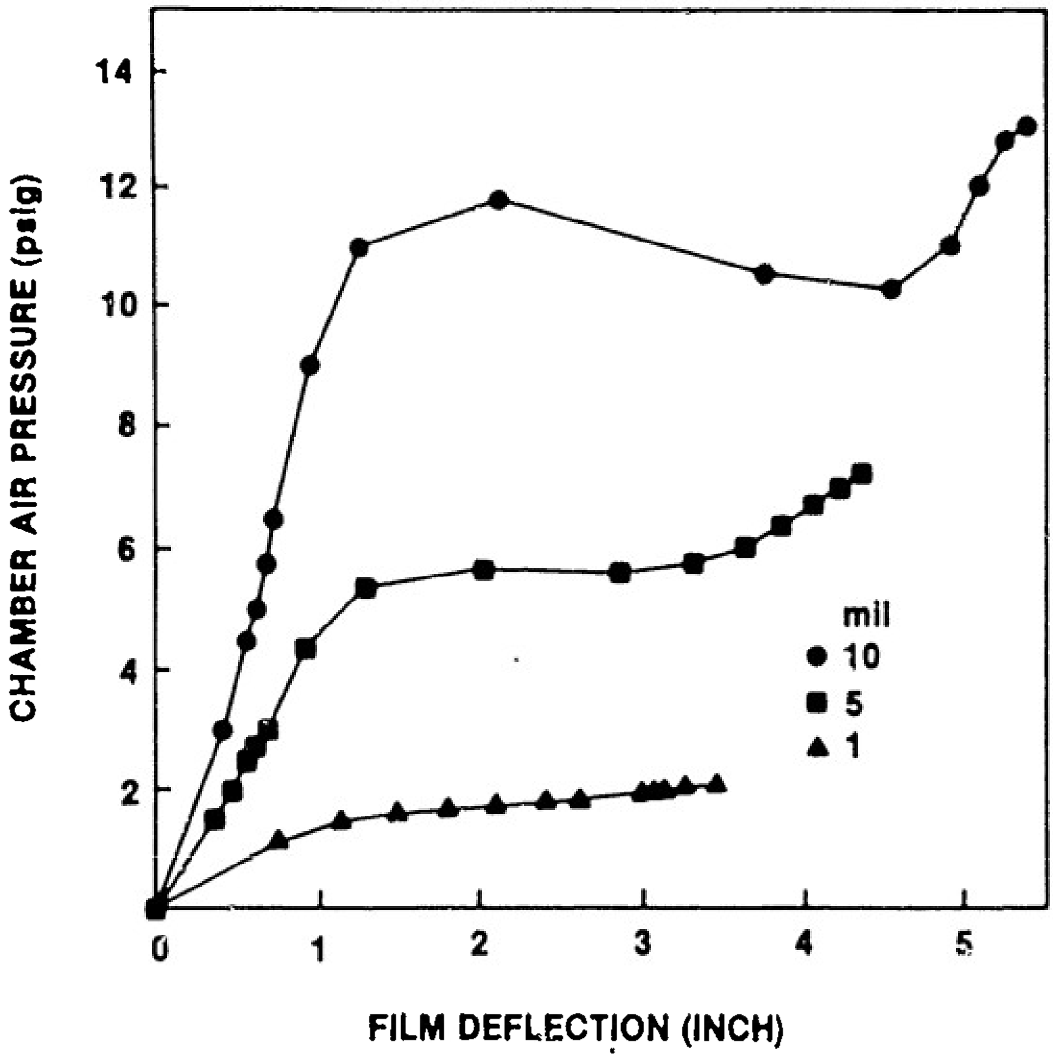

Figure 16. Measurements of chamber air pressure vs film deflection for 4"-diam. polyurethane films.

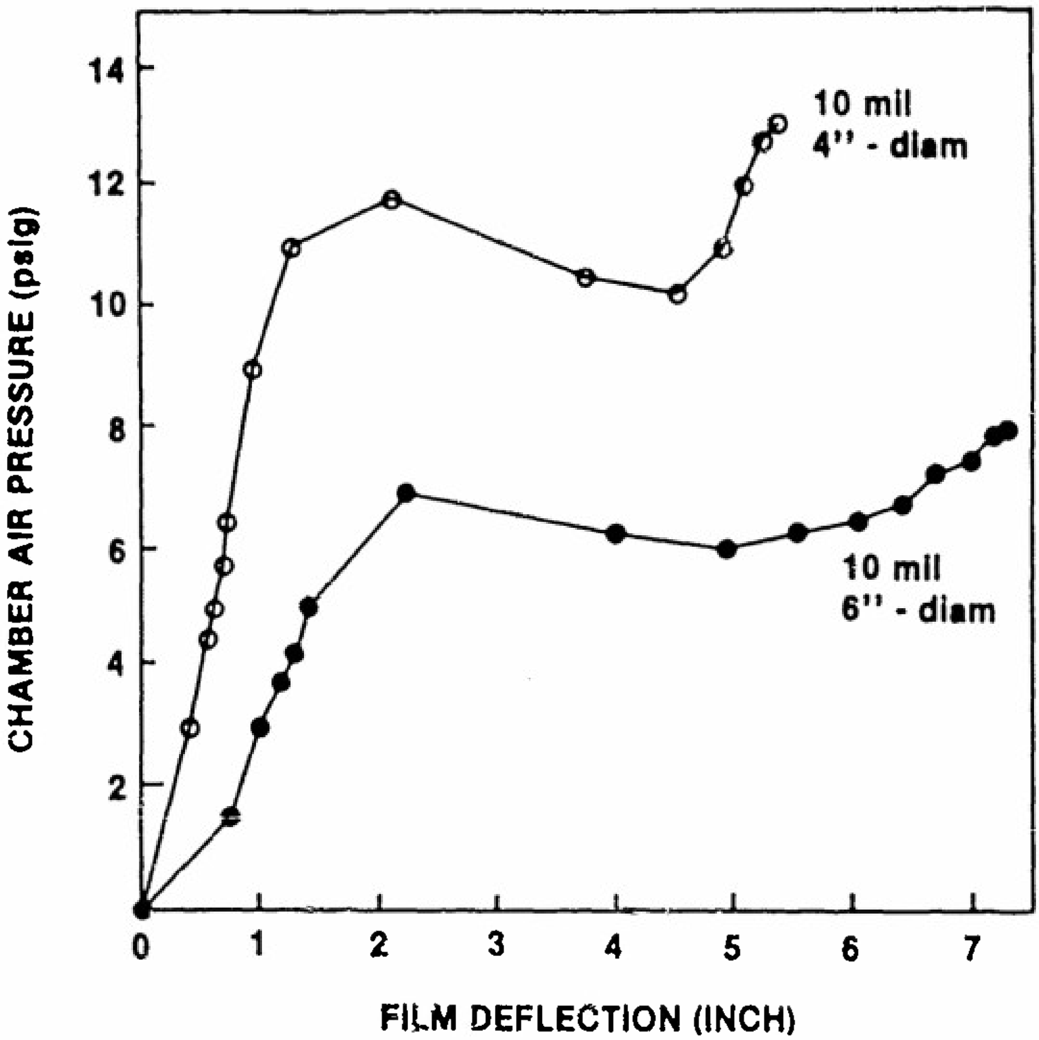

Figure 17. Measurements of chamber air-pressure vs film deflection for 4"- and 6"-diam. polyurethane films.

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APPENDIX

BURSTING AIR PRESSURES OF PLASTIC FILMS

1. Linear Low Density Polyethylene

Sample (4"-diam)	Thickness (inch) 0.00053	0.00080	0.00120
	0.88(psig)	1.25	1.75
	0.88	1.25	1.62
	0.88	1.12	1.75
	0.88	1.25	1.62
	0.75	1.25	1.75
	0.75	1.20	1.62
	0.88	1.25	1.62
	0.88	1.12	1.75
	0.88	1.12	1.75
	0.75	1.25	1.87
Average (psig)	0.84	1.21	1.71
Standard Deviation (psig)	0.06	0.06	0.08

2. Polyethylene Terephthalate

Sample (4"-diam)	Thickness (inch) 0.00048	0.00092
	5.00(psig)	18.25
	4.88	19.25
	6.25	17.50
	7.13	19.25
	5.00	18.50
	6.00	19.00
Average Bursting (psig) Strength	5.71	18.63
Standard Deviation (psig)	0.83	0.62

3. Oriented Polypropylene

Sample	4"-diam Thickness (inch) 0.0005	0.0010	0.0015	6"-diam Thickness (inch) 0.0010	0.0015
	6.75(psig)	15.00	22.75	9.75	12.13
	7.25	12.00	21.75	10.25	13.50
	5.00	13.75	22.50	10.50	13.00
	6.00	12.75	15.00	10.25	10.75
	5.00	11.25	21.50	8.00	13.50
	4.00	12.50	23.25	10.50	10.75
	5.25	10.88	18.00	8.50	13.25
	5.50	11.00	20.00	10.25	13.50
	6.00	13.00	17.00	9.6	13.00
	5.63	11.25	19.25	9.12	13.75
Average Bursting (psig) Strength	5.13	12.34	20.10	9.68	12.71
Standard Deviation (psig)	1.83	1.27	2.61	0.83	1.07

4. Flexible Polyvinyl Chloride

Sample (4"-diam)	Thickness (inch) 0.0008	0.0010	0.0020	0.00065
	1.25(psig)	1.25	2.50	1.00
	1.25	1.20	2.50	0.88
	1.00	1.25	2.37	1.12
	1.12	1.20	2.50	1.12
	1.35	1.20	2.50	1.00
	1.25	1.20	2.25	1.00
	1.20	1.25	2.37	1.00
	1.25	1.20	2.25	1.12
	1.20	1.30	2.25	1.00
	1.20	1.20	2.25	1.12
Average Bursting (psig) Strength	1.21	1.23	2.37	1.04
Standard Deviation (psig)	0.09	0.03	0.11	0.08

5. Polyurathane

Sample	4"-diam Thickness (inch) 0.001	0.005	0.010	6"-diam Thickness (inch) 0.010
	2.00(psig)	7.25	11.25	8.75
	2.25	7.75	13.00	8.25
	2.12	7.75	13.00	8.00
	2.00	7.00	13.25	7.50
	2.37	7.00	13.25	7.50
	2.00	6.75	13.00	7.50
	1.88	7.00	13.75	7.50
	2.12	7.12	13.00	7.00
	2.37	7.12	13.75	8.00
	2.00	7.12	13.00	8.25
Average Bursting (psig) Strength	2.11	7.19	13.03	7.83
Standard Deviation (psig)	0.16	0.31	0.66	0.49